

ENQUIRY INTO THE PRESSURE AND RAINFALL CONDITIONS OF THE TRADES-MONSOON AREA.

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In 1900 the writer undertook the discussion of the seven monsoon seasons 1893 to 1899 and showed that during those seven years there occurred a series of oscillations of pressure and that between these oscillations and the monsoon rainfall over India there existed a very distinct and marked relationship. The data used in this discussion consisted of the mean monthly and seasonal variations of pressure over India, derived from all the stations employed in the Daily Weather Report of the Meteorological Department, and the mean monthly and seasonal variations of pressure over the Equatorial Belt and the Arabian Sea as given by the pressure observations recorded (1) at the Seychelles, Zanzibar and Mauritius and (2) on board ships traversing the Arabian Sea and the South-east Trades Region.

The relationship as established for those seven monsoon seasons was as follows: (1) The Indian monsoon rainfall was in defect during the rising portions of these pressure oscillations and in excess during the falling portions while the amount of the rainfall variation agreed directly with the rapidity of the pressure changes. (2) The pressure oscillations exhibited a periodicity of about four years.

It was carefully pointed out at the time that the discussion dealt solely with the seven years under review so that, though the agreement there disclosed was exact and clear, it was obvious that a much longer series of observations would be required before it would be safe to assert that the period of the oscillations and the relationship between the pressure oscillations and the rainfall, as disclosed in the discussions, could be accepted as having a general application. As a matter of fact, before the publication of the paper, it had already become apparent that the relationship had not been maintained, while a simple examination of the existing rainfall data of India showed that there does not obtain any simple

four-year cycle in the Indian rainfall. The author believes that these four-year oscillations form the basis of the weather changes over the Indian monsoon area, though there occur at times violent or spasmodic interruptions, the cause of which is not as yet apparent, and that these interruptions are the cause of the great irregularities in the course of the pressure cycle and in the occurrence of the variations of rainfall. Since the history of these seven monsoon seasons was written, Professor Bigelow's "Contributions to Cosmical Meteorology" ¹ has appeared. In it the following paragraph occurs :

"The increase of solar magnetic intensity is synchronous with a diminution of temperature but with an increase of pressure and this function persists throughout every phase of the research. In spite of some irregularity there is a distinct conformity in the general sweep of these curves and also in the tendency to describe crests during the same years. Indeed the occurrence of four subordinate crests in the 11-year periods suggests strongly that a $2\frac{3}{4}$ -year period is superposed upon the long sweep of that period curve. Apparently this minor period is the basis of the seasonal variations of the weather conditions of the U. S. A. more than anything else, so that in long range forecasting this period must be very carefully considered."

It will be noticed that the period of these minor oscillations as then determined by Professor Bigelow was $2\frac{3}{4}$ years for the United States. Subsequently Professor Bigelow produced his "Report on the Barometry of the United States" and from the complete data there employed he obtained an eight-year cycle of pressure which is a simple multiple of the four year cycle determined for the Indian Monsoon Area. Professor Bigelow's researches terminate with the year 1899 but where they overlap the Indian series of observations the principal characteristics of the two series agree. Thus Professor Bigelow obtains a maximum in 1896 and a minimum in 1898 with pressure rising again to a maximum through 1899. In the Indian equatorial area the period is approximately four years, and the writer agrees in believing that these minor oscillations of pressure are mainly influential in determining the seasonal variations of weather. On this point it appears probable that the ex-

¹ See Monthly Weather Review, July, 1902, and especially, Weather Bureau Bulletin, No. 21, pp. 125-6, Washington, 1898.

perience of the Indian area will be found to correspond with that of the United States. It must however be born in mind that the investigation is one of extreme complexity and that superposed on the four-year or minor oscillation there are great irregularities which cannot now be explained but which at times completely upset the regular course of the cycle. Notwithstanding these irregularities and interruptions it appeared to the writer that in face of the remarkable agreement between the pressure oscillations and the rainfall during the years 1893 to 1899 it was worth while to continue the discussion in a more exact and detailed manner so as to determine (1) over what area the pressure oscillations extended (2) how far they agreed in amplitude and in time throughout the affected area and (3) what relation the rainfall of the whole monsoon area bore to the pressure oscillations.

The author has collected and discussed a large amount of material and has arrived at certain conclusions which he regards as tentative and far from satisfying. He feels doubtful if the observations would fulfil the requirements which Professor Schuster laid down as a means of estimating the reality of the periodicity, but the investigation has brought out certain relationships which appear at least worthy of record.

The tentative conclusions arrived at are as follows:

(1) That over the trades monsoon area—and most markedly so over the equatorial belt—there occur four-year oscillations of pressure; (2) that during the rising portions of these oscillations the *general* rainfall of the trades monsoon area is below, and during the falling portions is above the average, with a well-marked minimum of rainfall in the first year of the cycle and a well-marked maximum of rainfall in the third year; (3) that from the Antarctic or extreme southern regions there emanate at irregular intervals rays or streamers of varying extent and intensity which occasion increased atmospheric pressure over the affected area; (4) these rays or streamers are apparently not in the least in the nature of waves, as they affect large areas practically simultaneously and continue for considerable periods; (5) when these rays or streamers are frequent and extensive, as in portions of the years 1899 and 1900, pressure ranges largely above the normal, but exhibits large oscillations or fluctuations; when on the contrary they are absent as in portions of the years 1898–1899 pressure is low and the oscil-

lations small; (6) these variations are superposed on the four-year cycle of the tropical belt, and are spasmodic, occurring at irregular intervals over irregular areas so that their influence occasions irregular variations of rainfall and irregularities in the pressure cycles.

There appears to be no satisfactory explanation either of the four-year cycle of pressure over the trades monsoon area or of the irregular spasmodic disturbances of pressure referred to above. With regard to the cycles it is possible that compensatory actions are at work, so that when atmospheric pressure increases in one part of the world it decreases in another, though the evidence of the barometry of the United States is opposed to this and rather suggests that the principal secular variations of pressure are of a uniform character over the whole globe. It is impossible to believe that the variations of pressure are a *result* of variations of rainfall. For one thing, the variations are as marked in a dry area like Aden as in a wet area like Bombay, and for another, the evidence, so far as it can be sifted, shows that the variations of pressure *precede* the variations of rainfall. Thus the increase of pressure which culminated in the large excess of pressure in the months of July, August and September, 1899, commenced in February of that year, thus *preceding* by some months and not *succeeding* the scanty rainfall of that season.

The memoir contains all the figures and data on which the enquiry is founded. Some of the observed changes are at present quite inexplicable, but the observations are given as recorded so that though the author has not succeeded in obtaining any conclusive results, it may be possible for other students of meteorology with more available leisure to work them into a more harmonious scheme.

In order to undertake this detailed examination the employment of pressure or rainfall means of large areas has been abandoned, and instead the actual monthly pressures and their variations for certain selected stations, which it is believed represent fairly adequately the whole monsoon area, have been used. The list of stations includes: Batavia, Calcutta, Bombay, Aden, Cairo, Madras, Colombo, Seychelles, Zanzibar, Mauritius, Durban and Perth, while in addition the marine observations of the Arabian sea and the Equatorial belt have been utilized to obtain averages for those

areas, mainly with the object of determining whether, in the case of these pressure oscillations, there occurs any horizontal translation in the pressure changes or whether they occur simultaneously throughout the whole area.

Numerous tables and figures are given in the memoir to assist in the discussion of the observations.

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